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RECENT LITERATURE ON THE BEHAVIOR OF THE LOWER INVERTEBRATES

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Protozoa.—Woodruff (35) has kept one race of Paramœcium for more than 2,700 "generations" without conjugation. At first he believed that this long period without the occurrence of sexual processes was due to the fact that he varied the composition of the medium in which the protozoans were kept. Recently he has propagated individuals from his original strain in a medium of unvarying composition (0.025 per cent. beef extract), and at a constant temperature, for more than ten months; there was no evidence of loss of vitality or decrease in the rate of fission, though there were small fluctuations which he ascribes to internal causes. Woodruff concludes that "the protoplasm of a single cell has the potentiality to reproduce by division indefinitely—under favorable environmental conditions—and therefore conjugation, or fertilization, is not a necessary phenomenon for the continued life of protoplasm." In the same paper experiments are described in which the ability of Paramœcium to withstand various chemicals in solution was tested. "There is a marked parallelism between the order of the toxicity of many cations toward Paramœcium and the ionic potentials of the ions. . . . Subjection to small amounts of alcohol increases the susceptibility of the organisms to copper sulphate." Excretion products have a depressing effect on the rate of reproduction and are the chief cause of the usual succession of protozoan species in hay infusions (34). Each species is killed by the accumulation of its own metabolic wastes.

Jennings (17) shows that there is assortive mating for conjugation in Paramœcium. Individuals of different species do not conjugate with each other, nor do races of different sizes in the same species. The descendants of conjugants are more variable than those of the non-conjugants. A very interesting account of the behavior of Paramœcia during the process of getting in position for conjugation is given. A pair usually adhere first by their anterior ends, though they may assume other positions and then adjust themselves. Both the anterior end and the region about the mouth are more adhesive than other parts of the body.

Gruber (15) has made a very careful study of various activities of mutilated specimens of *Amœba proteus* with the particular object of comparing the behavior of nucleated portions with that of enucleate fragments. Pieces without a nucleus remained active for a longer or shorter time and were able to form a pulsating vacuole which functioned in the usual way, but never showed powers of regeneration, and ultimately died in all cases. Nucleated fragments cast out material from the nucleus; the writer believes that this was to maintain a definite proportion between the amount of nuclear and cytoplasmic material.

The galvanotropism of Gonium, as reported by Moore and Goodspeed (24) presents several points of interest. A colony of these flagellates, when subjected to a constant electric current, orients itself with the anterior flagellated surface toward the cathode and continues to swim toward that pole. When the current is allowed to act several minutes galvanotropism "reverses and finally disappears." Apparently an excess of H or of OH ions in the medium causes the galvanotropic response to change from cathodal to anodal. There is no reversing "motor reflex" as in Paramœcium and some other ciliates, but turning is accomplished by movement in a half circle, the flagellated surface always moving ahead. Individual cells and fragments of colonies behave in the same manner; and therefore "the reversal of the colony may be due to the reversals of its constituent cells." Moore maintains that "since the flagella of Gonium are situated all on one side, the reversal of the current cannot bring about a reversal of the colony by a differential beating of the flagella as in Volvox."

Wieweger (33) has studied the behavior of ciliates toward various chemicals and gives a very complete review of the literature. He distinguishes trophotaxis or anataxis to nutritive substances, areotaxis, hydrotaxis, alkaliotaxis and oxytaxis (sensitiveness to alkalies

and acids). He points out that Paramœcium manifests kata- or ana-taxis, according to the degree of concentration in the medium, and asserts that such reactions are independent of the osmotic pressure. The sensibility to chemical substances is constant, but "anaoxytaxis" is variable. Stimulation by acids is due to the passage of + H ions into the protoplasm. It is maintained that Jennings committed an error when he asserted that infusorians usually respond to all kinds of stimulation by a single general reaction (Did Jennings do this?) and many of the motor reactions of Colpidium and other species are said to be more complex than has been supposed. Positive reaction to acids is not reversed by the addition of alkalies but made very weak. Galvano- and chemo-taxis depend upon the chemical reaction of the medium. The salts of alkali and alkali-earth metals alter the sensibility of Paramœcia by diminishing usual orienting reactions.

In her paper (21) on the life history of the two ciliates, *Spathidium spathula* and *Actinobolus radians*, Miss Moody discusses the behavior of these interesting protozoans. Spathidium eats nothing but the ciliate Colpoda, and is said to use the trichocysts about its mouth in paralyzing its prey. Actinobolus is a peculiar ciliate with long radiating tentacles which are used in capturing food. It eats nothing but the infusorian Halteria, which is passed to the mouth opening by the tentacles and ingested. The writer points out that both these animals select one particular sort of food, and asserts that "it is evident . . . that the trial-error explanation is inadequate" in attempting to explain their feeding behavior. Neither eats anything but its regular food, even when hungry. The reviewer does not see why the behavior does not fall under the class of reactions that Jennings called "trial and error." The writer says in regard to Spathidium (p. 355): "As the animal swims rapidly through the water, rotating on its long axis, the anterior end of the body, which is extremely flexible, is in constant motion, bending upward, downward and from side to side as though feeling its way. Owing to this constant change of position, this region continually presents new aspects." Actinobolus (p. 371), "with partly retracted tentacles, rotating on its long axis, swims occasionally near the surface of the water, coming to rest from time to time with the mouth downward, on the bottom of the culture dish, moored by means of the oral tentacles." "I have seen no further elongation of the tentacles at the approach of Halteria" (p. 572).

Sokolow (31) has made an experimental study of the physiology

of *Stenophora juli* Frantz and twenty-one other gregarines. He groups the movements of these protozoans under six classes which differ in the presence or absence of myonemes, gelatinous substance, locomotion, etc. Considerable evidence is offered to support the writer's hypothesis that locomotion is brought about largely by secretion of gelatinous substance rather than through the contraction of myonemes, as Crawley and others have supposed. Gregarines are active in alkaline media, secrete gelatinous substance, and may carry on locomotion in which myonemes are not concerned. They may move either with the anterior or posterior end in advance. In acid media they are "active without locomotion" and secrete little gelatinous substance. The jelly is not only necessary for locomotion, but protects the gregarines; various solutions show injurious effects which are in general proportional to the power such solutions have of dissolving the jelly.

In his monograph on the Acinetaria, Collin (9) has a chapter on the physiology of these interesting protozoans. Food is captured on the ends of the tentacles and taken into the body by suction, absorption, or actual ingestion. Suction is brought about by peristaltic waves that pass down the tentacles, the ectoplasm being the active layer. Digestion is remarkable because vacuoles are rarely formed; the food usually becomes a part of the endoplasm at once. Suctorians may exhibit ciliary or even amœboid movements in early stages of their development, but adults are usually sessile or sedentary. Some are able to swim like nematode worms, during certain stages. The tentacles make two kinds of movements, flexions, contractions and extensions, which are controlled by the contractility of the ectoplasm and by the general turgescence of the whole tentacle.

Cœlenterata.—Pax (25) gives an interesting review of the recent literature on the behavior of actinians and discusses its relation to psychology.

Platyhelmia.—Boring (5) placed planarians singly in a crystallization dish with water and illuminated one side of the body of each individual continuously by switching on or off six lights which surrounded the dish. He states that "planarians, if subjected to continued, intensive, directive light, continue turning away from the source of light. If they are immediately placed in non-directive light after being in directive light, they turn consistently in the direction from which the light first came." The writer believes such behavior indicates that the worms become "light-adapted" on one

side during exposure to directive light. This, to the reviewer, seems to be a new way of saying that the exposed side becomes fatigued. After continued illumination planarians show a tendency to reverse for a time, but this condition disappears if stimulation is long continued. Boring believes such reversals are due to compensatory muscular movements made in order to secure relief from continued turning. This explanation may be true, but does not appear to be wholly adequate. Planarians often reverse under strong stimulation when such "relief" would not be necessary, and if reversal does not bring relief from unfavorable stimulation they pass on to other "trials" such as twisting, protruding the proboscis, etc.

Annelida.—Yerkes (36) gives an interesting account of his experiments planned to test the intelligence of the earthworm, *Allolobophora fœtida*. His paper deals with the behavior of one worm that was under observation for an entire year. This individual was tested daily in a simple T-shaped labyrinth having one entrance and two exits. One exit led into a tube of moist blotting paper; a strip of sandpaper stretched across the floor of the other, and the worm received an electric shock if it went across this. The worm soon avoided the sandpaper followed by electrical stimulation and escaped from the free exit more quickly after several trials, but never gave "perfect" records day after day. When the free exit and that containing the sandpaper and electrodes were interchanged, the worm persistently turned in the direction it had formerly used for exit, but after a time formed a new habit to suit the altered conditions—and even gave evidence that it associated the tactual sensation received from the sandpaper surface with the electrical shock which usually followed.

At this point four and one half segments were cut away from the anterior end of the worm. When tested forty hours after the operation it showed a tendency to climb and to use its posterior end in testing its surroundings, but also gave evidence that it retained the habit previously formed. The "brain" was not essential in order to "remember" the direction of turning or to "recognize" the exit tube. The responses at this time were markedly stereotyped. After a month of testing the worm was allowed to rest for four weeks, and the original habit had then degenerated. Yerkes believes this retrogression was due to the growth of a new brain which had established connections with the ventral nervous system. By renewing the training for two weeks the worm was brought back to the route it had been accustomed to use before its anterior end was amputated, though it had a tendency to turn in the opposite direction.

Jordan (18) observed the reactions of earthworms that were attempting to pull leaves into their burrows. He maintains there is no evidence of "intelligence" (Darwin) or of "reflex adjustment" (Hanel). These animals grasp a leaf anywhere. If it will not pass into the hole they release their hold and try again and again until they hit upon a favorable position. In the majority of cases the leaf finally enters the hole point first. Earthworms do not feel around the edge of a leaf to find its point, as Hanel supposed. Jordan gives evidence to show that they hold leaves through the sucking action of the pharynx; the blood being forced into the lips to make a firm disc which is applied to their surfaces. The observations show that the reactions of earthworms in dragging leaves to their burrows are wholly in accord with the method of trial as described by Jennings.

Lillie and Just (19) report some interesting observations on the breeding habits of a heteronereis (*Nereis limbata*) at Woods Hole, Mass. Mature worms swim at the surface of the ocean at night during the "dark of the moon." The males appear first and always exceed the females in number. When a female appears she is immediately surrounded by several males which shed sperm. She soon begins to lay eggs. The males shed sperm regularly when stimulated chemically by some substance (probably the egg secretion which is known to agglutinate the spermatozoa) given off by the female into the water. A female will not lay eggs unless the water around her contains sperm. Both eggs and sperm shedding are reflexes which may be regulated by the application or withdrawal of the appropriate stimuli.

Lund (20) records observations made in Montego Bay, Jamaica, on certain luminous animals, and confirms Galloway's assertion that the emission of light by some marine worms is effective in bringing the sexes together. When illuminated by a small incandescent globe certain Cirratulidæ "swam toward the source of stimulation, at the same time becoming brilliantly luminous."

Echinodermata.—Cole (7) tested ten starfishes (*Asterias forbesi*) in aquaria illuminated by light from above, to ascertain whether they had a tendency to crawl with a particular ray or rays in advance. Each individual was given fifty successive trials. The writer concludes that starfishes have a "physiological anterior" which is indicated structurally by the madreporite. He also observed that, though a starfish manifests an "impulse" to crawl with a certain region of the body in advance in successive trials, there is a tendency for this impulse to shift or rotate around the body in one direction or

the other. The "physiological anterior" of starfishes corresponds structurally to the well-marked anterior end of the bilateral sea-urchins, and its position is perhaps due to mechanical causes, *e. g.*, the presence of the madreporite, stone canal, etc. In another paper Cole (8) records the results of certain experiments in which starfishes were tested after the radial nerves of the oral systems had been cut. He concludes that his experiments "seem to demonstrate, in so far as they go, the failure of the establishment of coördination or 'unified impulses' in the starfish by direct pull of one part upon another when the nervous connection between these parts has been severed."

Mollusca.—Bauer (3) has investigated the reactions of the scallop, *Pecten jacobæus* L. The food of this mollusc consists of microscopic plants, and a plentiful supply is insured by the reactions to light. Pecten orients its body with the hinge toward the light so that swimming movements carry it into shallow water and into illuminated areas. Small quick-moving shadows cause Pecten to withdraw its tentacles; but a large shadow or a small slow-moving shadow cause no such response. The writer believes these reactions are adaptive, withdrawal of the tentacles being to protect them from small predaceous fishes, and that the diverse responses to different shadows depend upon an adjustment controlled by the peripheral nerve net. A small shadow that does not move quickly will cause a Pecten to stretch the tentacles and eyes on the nearest side toward it. This enables him to ascertain the proximity of a starfish—his worst enemy—and to swim away. Small foreign objects are eliminated from the exposed fleshy surfaces by local squirting reflexes. Touch and chemical sense work together to protect the scallop from his enemies. Starfish extract always causes active swimming movements. Pecten maintains a definite relation to its environment in that it rests on the right valve and performs a characteristic righting reaction if placed on the left. This reaction is apparently under the control of both the eyes and the statocyst, for it takes place in total darkness or after the cerebro-visceral commissure has been cut.

Grave (14) reports that the statocysts of certain Pinnidæ appear to be degenerating. Such organs are lacking in most of these molluscs, and when present, they are compound or show other abnormalities. Furthermore, Pinnas which have had their statocysts removed show no change in their behavior. The writer therefore concludes that "the otocyst of the Pinnidæ is undergoing degeneration, and is at present of no functional value."

Piéron (26, 27) has investigated the light reactions of the pond snail, *Limnæa stagnalis*, with particular reference of the effect of previous stimulation on such responses, and he attempts to make general application of his results in revising Ebbinghaus's law of memory. In his first paper he describes the results of experiments in which snails were subjected to shadows of a definite duration at regular intervals. The number of shadows required to bring the snail to a condition when it did not withdraw its tentacles was thus determined. Subsequent experiments showed that the training had some effect, *i. e.*, the snail ceased to respond more quickly when tested a second time. In his second paper the writer attempted to determine the interval between periodic shadows which would make snails cease to respond most quickly, and found it to be from ten to twenty seconds.

Polimanti (30) studied the movements of certain pteropods and heteropods in detail, and describes experiments which elucidate the functions of various parts of the nervous system in these animals. If one statocyst is destroyed, an animal rotates toward the uninjured side; if both are destroyed, power of orientation is mostly lost and this condition is even more pronounced if the eyes are also removed. Injury to the cerebral ganglia causes an increase in general irritability. The pedal ganglion coördinates muscular movements and controls locomotion.

Crustacea.—Allee (1) has investigated the reactions of aquatic isopods, chiefly *Asellus communis* Say, to currents, with particular reference to physiological states. He asserts that "while it is as yet impossible to control with certainty all the minor details of the reaction, yet sufficiently complete control has been maintained to show that in the rheotactic response with these animals there is no necessity for any 'factor foreign to organics' in order to explain the changes in physiological states." Though the same species of Asellus was tested from both ponds and streams, the reactions of the individuals from the two habitats were quite different. Isopods from ponds were usually indifferent to currents or showed a weak positive rheotaxis; those from streams gave definite positive reactions as a rule. After carefully testing the environmental factors that might be responsible for such differences, Allee concludes that the amount of oxygen present in the water is not the most potent factor. Immersion in water with a high oxygen content will soon cause pond isopods to become positively rheotactic to a marked degree; water with a small amount of oxygen brings stream isopods

to a condition resembling that of their pond relatives under natural conditions. Chloretone, potassium cyanide, low temperature or a sudden increase to a high temperature, carbon dioxide, and starvation all decrease positive rheotaxis (like low oxygen content; caffein has the opposite effect, like high oxygen content). The degree to which Asellus shows positive rheotaxis depends upon the metabolic state. All the conditions that cause a decrease in this reaction are known to depress the rate of animal metabolism.

"Taxonomic differences are inheritable characteristics of the species, and are not dependent upon external conditions, while the behavior characteristics studied are almost independent of heredity." Shelford's term "mores" is used to express the physiological differences between isopods from streams or ponds—*i. e.*, there are stream or pond mores which have a characteristic type of behavior, irrespective of the differences or identities of species. "The general conclusion to be drawn from this series of experiments is that in the isopod, *Asellus communis*, the rheotactic reaction is dependent upon the metabolic state of the animal for its degree of positiveness and that the natural or experimental conditions which affect the metabolic state of the animal change its rheotactic response. That is to say, the rheotactic reaction is here an expression of the metabolic condition (physiological state) of the isopod and may be controlled by those factors known to control animal metabolism."

Polimanti (28) discusses the association of the anomuran, *Dromia vulgaris*, with the sponge, *Suberites domuncula*. Like many other crustaceans of the family Dromiidæ, the crustacean carries a sponge on its back for concealment. He affirms that such a covering does not come on the crustacean's back by accident, but is placed there by the individual that bears it. Dromias placed in an aquarium with two Octopi remained uninjured for more than a month when they had a covering of sponge, but were devoured in a day or two when they were without such protection. Polimanti believes that Dromia's decorating reactions show evidence of associative memory.

Stevens (32) has done a very good piece of work in testing the chromotropism and decorating activities of the spider crab, *Oregonia gracilis*. His experiments were performed in aquaria and in a simple maze that floated in the ocean at Friday Harbor, Washington. Crabs that were placed for 24 to 36 hours in aquaria covered by blue, green, yellow, or red screens established a positive chromotropism for the colors thus used. For example, a crab kept under red glass and subsequently placed in a box where a choice was permitted between

red and another color, went toward the red in the majority of its reactions. In placing objects on their carapaces the crabs did not select colors which matched the background on which they rested, nor did they use colors that corresponded to color screens under which they had previously been exposed. Blinded crabs which did not respond to photic stimulation attached objects to their backs like normal individuals. There is no evidence that decorating reactions are brought about by anything but tactual stimulation, and, though it is still possible that visual and tactual stimulation might work together, there is no experimental evidence to show that vision is at all concerned.

Bauer (2) has investigated the effect of light on the chromatophores of shrimps. Though light has a direct effect on the general reactions of shrimps and influences the metabolism to some extent, there is no true photosynthesis with fat as its end product, as some have maintained. However, fat is deposited more rapidly in the skin under the influence of light. The chromatophores act as a light screen for the subdermal tissues, and are regulated in part by photic stimulation through the eyes.

Moore (22) found that *Daphnia pulex* was negatively phototropic to ultra-violet light, *i. e.*, to wave-lengths shorter than 3,341 Å. μ. Negative phototropism induced by such stimulation was reversed when small quantities of carbon dioxide or hydrochloric acid were added to the water containing the crustaceans.

In another paper Moore (23) describes the effects of certain chemicals on photic reactions. When strychnine was added to water containing crustaceans, the usual positive reaction to light disappeared for some time, and one species, *Diaptomus bakeri* (?), became negative. Caffeine "caused a positive collection; atropine brought about a marked tendency to form a negative collection but in a much less degree than strychnine. It may be of significance that in vertebrates caffeine acts as an excitant only for the higher centers and strychnine for the lower, while atropine occupies a position midway between the two." Agents which usually cause Diaptomus to become positive will reverse negative phototropism induced by strychnine. In addition to acids, camphor, which is an antidote for strychnine in vertebrates, will cause such reversal. "While negative phototropism in Diaptomus can be reversed by acids and camphor, positive phototropism brought about by chemical means cannot be reversed by strychnine."

Fasten (12) has investigated the behavior of *Lernæopoda edwardsi*,

a parasitic copepod which attaches itself to the gills of the brook-trout. Apparently this crustacean is accurately adjusted to its host, for it will not fix itself to the nearly related rainbow- or German-brown-trout. During its short free swimming existence (about two days) it swims actively with a "darting spiral motion," which enables it to cover a great amount of space and thus increases its chances of finding a host. The copepod "is so strongly attracted by intense light that during the day it frequents the upper regions of the water, though it is normally positively geotropic"; in light of low intensity it is indifferent and is found at the bottoms of the ponds where it lives. Both these positions are advantageous, for the brook-trout feeds near the surface during the day and descends into deeper waters at night. It is interesting to compare the behavior of this parasitic copepod with that of its free swimming pelagic relatives, which generally migrate upward at night and downward during the day. In attaching itself to the gill of the trout, Lernæopoda inserts its mouth parts into the flesh, rasps a cavity with its second maxillæ, and then injects the attachment filament at the front of the head.

Esterly (11) has made a very thorough study of the distribution and diurnal migrations of nineteen species of marine copepods occurring near San Diego. Most of these crustaceans make vertical migrations so that "the epiplankton is more populous at night, the mesoplankton during the day. . . . The data available from the records of this station do not show that the abundance of any of the species is related to temperature or salinity." Ten species were taken at the surface in large enough numbers for judging as to when they reach their maximum abundance. Three are most numerous between 6 and 8 P.M., five between 8 and 10 P.M., one between 10 and 12 P.M., and one between midnight and 6 A.M. Many species leave the surface before the light increases in intensity; several never come to the surface. Esterly believes that light is the chief factor that induces the periodic diurnal movements of the copepods he studied, though he admits that its action will not account for downward migration and some other features of the behavior.

Franz (13) summarizes several of his recent papers, and reaffirms his belief that the so-called phototropic reactions of animals are not generally similar to those of plants. He believes that the photic responses of animals as determined by laboratory experiments are mostly due to attempts to escape (*Fluchtbewegungen*). Those organisms which are seeking an open space are positively phototactic; those that are attempting to hide are negative. Franz will not admit

that light plays an important part in the daily migrations of plankton organisms, and even asserts that more individuals are captured at night because they cannot see the net and escape (!). He maintains that animals do not react to light as such, but because it is a sign of a means of escape. The argument is well presented and supported by careful evidence, but there are, of course, serious objections to Franz's broader generalizations.

Hess (16) opposes Loeb's theory that there is essential identity in the photic reactions of plants and animals. He tested *Artemia salina* in a black tube with a light at either end. One of the lights was fixed and the other movable. By varying the intensity and colors of the two lights he was able to study Artemia's sensitiveness. Another method was used in studying chromotropic responses. A cubical aquarium was divided into four compartments and illuminated from one side by light which came through a spectrum. One compartment was thus illuminated mostly by red light, another by orange and yellow, etc. A long cylindrical light was placed on the opposite side of the aquarium so that it could be moved back and forth in such a way as to neutralize the effects of the spectral light. The point at which the negatively phototropic Artemias turned from one of the sources of light gave indication of their brightness sensations. The writer concludes that the brightness values of the colors thus measured were about the same as those in a color-blind human being.

Lund (20) states he observed an ostracod in the ocean at Jamaica that gave off a drop of luminous secretion when a light was flashed upon it.

Chidester (6) gives an extensive review of the literature on the bionomics of the common crayfish, and supplements this with rather brief accounts of some original observations. He believes young crayfishes have more acute "visual sensitivity" for moving objects than adults. As a result of field studies at night with an acetylene lamp, it was determined that adults would retreat from a strong light, but approached one of low intensity. When freshly cut meat and somewhat dry meat were put in an aquarium crayfishes turned toward the former, thus indicating ability to discriminate chemical substances at a distance in the water. From extensive observations of crayfishes in nature and in aquaria where conditions were made as much like their usual habitats as possible, Chidester concludes that these animals are most active at nightfall and daybreak, though "sexual feeling" may lessen the usual tendency to hide during the day. "Hibernation was well marked," some individuals remaining

sealed up in their burrows for as long as six weeks during the winter.

Bohn (4) tested the effect on lobster larvæ of the addition of a small amount of acid or alkali to sea water. He watched the larvæ several days and found that, though both acids and alkalies were "sensibilisators," their effects were not apparent after a few hours.

Embody (10) gives a careful account of the general ecology of four species of amphipods studied at Ithaca, New York, and other places. He embodies in his paper many interesting facts concerning food, breeding, resistance to maximum and minimum temperatures, enemies, etc. The observations will be of value to anyone who wishes to carry on experimental work with amphipods.

Polimanti (29) gives the results of extended observations on various marine animals in the aquaria at the Naples Zoölogical Station. His paper gives many notes on the activities and habits of animals that will be of use to one who intends to investigate the behavior of marine organisms. Various cœlenterates, echinoderms, annelids, crustaceans, molluscs, tunicates, fishes, and reptiles are discussed. All the animals considered show periods of rest (when there is little danger from enemies) and activity (when food is captured). In many cases these show no correlation with diurnal rhythms, though in general the greatest activity is at night. Temperature and light are the chief factors which control periods of quiet or activity. Active animals often have a shorter life than those which are more sluggish. The writer affirms his belief that phosphorescence often acts as a protective device. An animal when stimulated gives a flash of light which startles its enemy.

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RECENT LITERATURE ON THE BEHAVIOR OF THE HIGHER INVERTEBRATES

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Tropisms

Phototropism.—According to W. D. Hunter (16), up to 1912 only two experiments testing the effect of the Roentgen rays upon insects had been published: one by Forel and Dufour upon an ant, *Formica sanguinea*, and the other by Axenfelt upon the house fly. Forel and Dufour decide that the ant was not affected in any way by the rays; but Axenfelt insists that the house fly perceives these rays and responds to them in the same manner that it does to light. Recently three investigators, Hunter (16) and Morgan and Runner (21), have tested the effects of the Roentgen rays upon insects. Hunter tested a tick (*Calandra oryzea*) and Morgan and Runner the cigarette beetle (*Lasioderma serricorni* Fabr.). Hunter's interests were embryological and Morgan's largely psychological. The former decided that the Roentgen rays do not produce sterility, and the latter concluded that these rays have no effect upon any stage of the life of the cigarette beetle.

The experiments of W. P. Gee (13) seem to show that the scale insect, *Lecanium quercifex* Fitch, exhibits marked positive reaction to a 16 c.p. lamp.

In his investigations on the fire-fly, Mast (19) found that the male responds to the glow of the female by turning about and moving directly towards it. He considers this an unconscious mechanical reflex; but since the animal continues to move towards the female even after the flash has disappeared, he concludes that the orientation is not a tropism in the sense of Loeb. To quote him:

"Here we have a case in which it is clearly demonstrated that light does not act continuously in the process of orientation, as is demanded by Loeb's theories; a case in which it is clearly demonstrated that the continuous action of the stimulating agent is not necessary to keep the organism oriented."

Newell (22) records that both the male and the female rice weevils fly readily towards the light. This tendency is more pronounced on dark nights.

Riley (26) relates that dragon-fly nymphs normally swim rapidly away from the light; but that this reaction may be inhibited by contact. These reactions are not always precise, and Riley thinks that they are probably not purely mechanical, but that pleasure and pain play a part.

According to Lucy W. Smith (28), *Perla immarginata* Say is attracted at night by artificial lights.

C. H. Turner (32) has experimentally demonstrated that brightness stimulates the mason wasp, *Trypoxylon albotarsus*, to activity, and that darkness, or a dim light, induces passivity. The flights are pronouncedly random and there is no fixed relation between the direction of movement and the rays of light; hence Turner thinks this is not a tropism.

The field observations of H. B. Weiss (37) lead him to conclude that different species of mosquitoes exhibit dissimilar reactions towards light. Some are apparently equally positively and negatively phototropic, others respond only to one stimulus, and yet others are unequally positively and negatively phototropic. He groups thirteen species of mosquitoes according to the above classification.

Geotropism.—Having observed that the scale insect, *Lecanium quercifex* Fitch, when placed on a vertical piece of cork, climbs upward, Gee (13) concludes that it is negatively geotropic.

Thigmotropism.—Gee (13) reports that the scale insect, *Lecanium quercifex* Fitch, is positively thigmotactic. A young nymph, which had been turned on its back and upon the feet of which had been placed an unhatched egg, continued to juggle the egg for almost 30 hours, and the larva that hatched from the egg had trouble in freeing itself from the clutch of the juggler.

Wodsedalek (45), by means of carefully conducted experiments, has demonstrated that the most pronounced feature in the behavior of the Ephemeridæ nymphs, *Heptagenia interpunctata* Say, is a strong positive thigmotaxis. This it is which causes several specimens to

mass together in an aquarium, and which causes unattached forms to swim towards any stone placed in the aquarium. A temperature of 45° C. temporarily reverses this thigmotropism.

According to Weiss (38), about the middle of September the gravid females of the mosquito *Culex pipiens* become positively thigmotactic and seek dark places. After becoming acclimated to the dark quarters, the positive thigmotropism so completely replaces the negative phototropism that a strong light may be flashed upon them without producing any effect.

Sensations

Recently Regen (25) has conducted some experiments on the hearing of *Liogryllus campestris*.

Mating Instincts

Newell (22) has described the mating habits of the rice weevil, Phil and Nellie Rau (24) those of the mantis, Wodsedalek (44) those of *Trogoderma tarsale* Melsh and Lucy W. Smith (28) those of *Perla immarginata* Say.

C. H. Turner (31) has published a photograph of two copulating *Ammophilas*.

Mathewson and Crosby (18) observed three cases of the hymenopterous insects *Caraphractus cinctus* Walker copulating beneath the surface of the water.

As described by Mast (19), the mating of fire-flies is intensely interesting. At twilight both males and females appear. The females climb blades of grass and rest thereon, but the males fly about at from one to two meters above the earth, glowing at fairly regular intervals. If a male glows within five or six meters of a female, she usually responds with a flash of light. The male then turns towards her and glows again, to which glow the female responds in kind. After his intermittent glow has been responded to a few times, the male alights near the female and rushes about in an excited manner, glowing repeatedly and being responded to each time by a glow from the female. Sooner or later the antennæ of the insects come in contact and they mate. Neither vision nor smell, but this luminescence, brings the insects together. The female will glow in response to any intermittent flash, even to artificial light; but the male responds to no glow except that of a female.

Nest Building and Maternal Instincts

Hungerford and Williams (15) describe the nests and, in some cases, the maternal habits of the following Hymenoptera: *Pogonomyrmex occidentalis* Cress., *Chlorion cæruleum* Drury, *Trypoxylon texense* Sauss., *Crabro interruptus* St. Farg., *Odynerus annulatus* Say, *Loxostege sticticalis*, *Odynerus geminus* Cress., *Polistes variatus* Cress., *Halictus occidentalis*, *Anthidium maculifrons* Smith, *Dianthidium concinnum*, *Megachile* sp. (?), *Melitoma grisella* Ckll. & Porter, *Anthophora occidentalis* Cress.

In a short article one cannot do justice to Comstock's paper (6) on the evolution of spider webs. Probably the production of silk by spiders was not primarily for the weaving of webs. All spiders use more or less silk in caring for their eggs, and this was probably its primary use. Spiders living in tunnels strengthen them by means of silk. The most important step towards real web-building was the acquiring of the habit of spinning a drag-line. The first drag-line may have been a thread a spider was using in constructing a cocoon; later, however, a special kind of silk was evolved for this purpose. "The step from drag-line to web is not a great one. A spider spinning a thread wherever it goes would make a web if by chance it moved about in a limited space, as in some nook or corner. In such a web insects would be trapped, and thus might arise the habit of building webs for the purpose of trapping insects. The simplest webs made by spiders are irregular webs formed of the same kind of silk as the drag-line." The web of Pholcus is of this type. Then come the webs of the sheet-weavers, which are constructed of dry silk—the kind out of which drag-lines are made—but which have a definite form. Slightly higher than these is the web of certain Agelenidæ which is constructed of dry silk, is regular in shape and has a funnel-shaped retreat. All such webs simply impede the progress of insects, giving the spider a better opportunity to catch them. In many families of spiders glands for secreting a viscid silk have been evolved. The simplest webs of spiders producing viscid silk are those of the Theridiidæ, which are almost as simple as the webs of Pholcus; but the spider throws around the captive a viscid fluid. Other spiders use this viscid fluid to construct threads or bands in their webs. There are two types of webs composed of combinations of these two kinds of silk; in one the part formed of dry silk is comparatively generalized but the viscid silk is supported by a highly specialized band; in the other the foundation of dry silk is a specialized structure and

the partition composed of viscid silk is comparatively simple. Comstock describes in detail varieties of these two types.

Fighting and Food-Procuring Instincts

Hungerford and Williams (15) have described the food-procuring instincts of a few Hymenoptera, Moore (20) those of several species of caterpillars, Newell (22) those of the rice weevil, Phil and Nellie Rau (24) those of the mantis, Riley (26) those of dragon-fly nymphs, Smith (28) those of *Perla immarginata* Say, Turner (32) those of *Trypoxylon albotarsus*, and Wodsedalek (44, 45) those of *Trogloderma tarsale* Melsh and the nymphs of *Heptogenia interpunctata* Say.

Brocher (2) has performed a series of experiments which induced him to conclude that *Elmis æneus*, *E. volkmari* and *Stenelmis canaliculatus* obtain their supply of oxygen, not from the atmosphere, but from plants immersed in water.

Casteel's recent investigations (4) modify our conception of how pollen is collected by the honey bee. By contact some pollen adheres to the legs; but the mandibles and the tongue are used in removing the pollen from the blossom. The pollen collected by the legs is dry; that collected by the mouth parts is moist. The pollen is gathered into the pollen baskets in the following manner. The first pair of legs removes the pollen clinging to the head and the moist pollen collected by the mouth-parts. The second pair of legs receives this pollen, and probably some from the head, and conveys it to the third pair of legs. By rubbing one third leg against the other the pollen is compacted in the corbiculæ, the moist pollen causing the mass to adhere. In unloading, the middle legs shove the pollen from the third legs into the cell.

Chubb (5) reports that the Rev. N. Abraham, of Natal, observed a spider, *Thaissius spenceri* Chubb, catching small fish and feeding upon them, and that the Rev. Pascalis Boneberg, also of Natal, observed the same species of spider reacting in the same manner toward tadpoles and little frogs. In catching the fish, the spider rested with its hind legs clinging to a stone and the others spread out over the surface of the water. When a fish happened beneath the outstretched legs, they suddenly closed about it and the mandibles of the spider inflicted a paralyzing bite.

Frost (12) noticed three flies of the species *Desmonetopa latipes* Meigen dart under the legs of a spider, *Phidippus multiformis* Emerton, and suck the juices of a bug upon which the spider was feeding.

By confining certain bugs in closed jars for definite periods of time

and then replacing them with other live insects, Girault (14) was led to conclude that the vapors emitted by certain Heteroptera are stupifying, and often deadly, to various forms of insect life. He does not claim that these experiments, which were accompanied by control experiments, settle the protective value of these odors.

Certain bees collect from one kind of flower exclusively. This habit is called an oligotropism. Robertson believes that this instinct is the result of an effort on the part of bees to avoid competition. Lovell (17) is positive that this is an erroneous idea. He writes: "The majority of oligotropic bees, whether they be species of Colletes, Andrena, Perdita, Panurgius or Mellissodes, visit exclusively the Compositæ. This behavior tends to produce competition. . . . No satisfactory evidence has ever been presented to show that oligotropism is an effort on the part of bees to avoid competition."

Sladen (27) asserts that the honey-bee gathers pollen directly into the corbiculæ by scraping the inner sides of the metatarsals longitudinally. The legs are not crossed at all, Cheshire's statement to the contrary notwithstanding.

Belt states that *Polistes carnifex*, on capturing a caterpillar, reduces the whole insect to a pulpy mass, then rolls about half of it into a ball and carries it off. According to C. H. Turner (33), *Polistes pallipes* Lepel. behaves quite differently. "Lepidopterous larvæ captured for food are not stung. Grasping the caterpillar with her forefeet, the wasp rotates it on its longitudinal axis and gradually elevates it while she malaxates its posterior end until her jaws are filled with a ball of pulpy matter. The remainder of the insect is then dropped and the ball of pulp carried off to the nest."

Wheeler (40) noticed a stingless bee, *Trigona pallida* Latreille, of Central America, collecting the crude black oil used to destroy mosquito larvæ and mixing it with her own secretions to form the cerumen with which she constructed her honey pots. Another species, *T. bipunctata wheeleri* Ckl., was noticed using human excrement in manufacturing her cerumen. Yet a third species, *T. ruficrus corvina* Ckl., was observed collecting a malodorous liquid from the insides of garbage barrels. No wonder the honey of some wild bees produces sickness.

Parasitism

Ewing (10) states that parasites have arisen in the following ways, and that among the Acarina we find parasites that have been derived by each method: (1) by predaceous forms beginning to prey on individuals larger than themselves; (2) by scavengers passing from

feeding on dead tissues to feeding on such tissues attached to living organisms, and thence to feeding on the plants or animals; (3) by forms adapted to sucking plant juices transferring their operations to animals.

Miscellaneous Instincts

Death Feigning.—The death feigning behavior of the dragon fly has been described by Riley (**26**), that of the Ephemeridæ nymphs and *Trogoderma tarsale* Melsh by Wodsedalek (**44, 45**), and that of *Conotrachelus nenuphar* Herbst. by Gee and Lathrop (**13a**). The last mentioned investigators agree with Holmes and the Severins in thinking that this form of behavior has developed out of positively thigmotactic propensities.

Hibernation.—The prevailing notion has been that the spotted Rocky Mountain tick hibernates in the nymphal and adult stages only. Bishopp and King (**1**) state that this is an erroneous idea. Many individuals hibernate in the larval state, only a few in the engorged nymphal stage, and a few in the adult period.

Blaisdell (**3**) found large numbers of the tiger beetle, *Cicindela senilis*, hibernating beneath flat stones, at from none to three inches deep.

Acrobatism.—Wells (**39**) records a peculiar acrobatic feat of some small flies belonging to the genera *Microcerata* and *Brema*. The flies were observed resting suspended, by the hind legs, from a spider's thread. At intervals flies would leave the thread and then return and assume the suspended attitude.

Homing

Cornetz (**8**) criticises Szymanski's work and stresses his former contention that ants are guided, not by tropisms, but by an inner stimulus. Incited by a remark of Santschi's, Cornetz (**7**) conducted a series of experiments to see what effect the sun's rays can have on an ant after they have passed through an opaque screen. He shaded an ant of the species *Messor barbarus*, which had started out to forage, with a movable vertical screen 75 cm. wide. This screen was shifted as the ant moved. Occasionally the ant was allowed to be in the sunlight for a moment. After the ant had gone far enough to make it possible to predict its line of march, it was shielded with an umbrella and the screen was arranged horizontally, one centimeter from the ground, at a short distance in front of the ant. When the ant arrived at the dense shadow cast by the screen, it halted, made a turn of ninety degrees, skirted along the shadow until the end of the screen

was reached and then turned about and moved on in a line parallel to the original direction. Cornetz reasons that if the ant could perceive the rays of the sun passing through the vertical screen, it should be able to sense the same rays when the screen is in a horizontal position. This ant was not guided at all by the sun's rays that had penetrated the screen. Shadows cast by screens are shadows for both ants and man. Ants are accustomed to shadows cast by vertical bodies; but the dense shadows cast by horizontal screens are seldom encountered outside of the nest. On encountering a strange object afield, ants usually either pass around or climb over it. Cornetz repeated this experiment with *Tapinoma* sp. (?), a species of ant that is much more blind than Messor. The ant continued on through the shadow and reappeared on the opposite side of the screen. Cornetz concludes that rays of light sometimes furnish ants with additional, but not indispensable, information.

Piéron (**23**) has made a critical review of all of the important papers that have appeared on the homing of ants, and repeated his former experiments. He thinks the theory that ants are guided home by an olfactory trail is well established for those ants that follow the same path going from and returning to the nest, but he does not believe that "being led by an odor trail" will account for the homing of all ants. He contends that C. H. Turner's conclusions are true merely in the immediate environment of the nest, and considers Cornetz guilty of too great a generalization when he claims that ants, when near the nest, always hesitate and describe what Cornetz calls a "tournoiement de Turner." He admits that light plays a rôle in the homing of ants, and believes that there is a zone adjacent to the nest in which ants are guided by sensory impressions, the dominant sense depending upon the species. At a distance from the nest, he thinks ants are guided by a kinesthetic sense, and he believes that there is an inner organ of the sense.

C. H. Turner (**33**) observed that *Polistes pallipes*, when it intends to revisit a place, makes careful flights of orientation. This caused him to conclude that a memory of the environment guides this wasp.

Memory and Learning by Association

C. H. Turner (**30**) watched a solitary wasp drag a caterpillar home. When first observed it was moving in a bee line for the nest. On the way the wasp encountered a tall board fence, up which she attempted in vain to drag the caterpillar. She then dragged the burden along the entire length of the fence until the end of the yard

was reached. Then she passed around the fence, turned at an acute angle and dragged the caterpillar to the nest. This line was not parallel to the path along which the wasp originally attempted to reach the nest. Turner concludes: "The behavior of this wasp does not harmonize with the theory that the movements of wasps are tropisms in the sense in which the term is used by Loeb; nor is it apparent how it can be the result of what Thorndike calls 'trial and error' movements. Her whole attitude is that of a creature struggling against obstacles, to attain a certain known place in a known environment."

To test their ability to acquire new responses to light, C. H. Turner (34) has conducted a series of experiments upon roaches of both sexes and all ages. Marked individual roaches were given an opportunity to enter either a dark chamber or a lighted chamber. Whenever the roach entered the dark chamber it was given an electric shock. After a certain number of attempts the roach would refuse to enter the dark chamber; indeed, after a certain amount of training, the roach could not be shoved into the dark chamber without offering resistance. After such a roach had been well trained it was transferred to a pen with a different kind of floor, but one in which the roach had an opportunity to enter either a dark or a lighted chamber. The roach would immediately enter the dark chamber. It was then returned to the former pen, when it again refused to enter the dark chamber.

From these experiments the following conclusions were drawn: "(1) By means of electric shocks roaches can be trained to avoid entering a specific dark place. This is not a reversal of the phototropic responses of the roaches, but the result of learning to avoid a specific dark place because of certain disagreeable experiences associated with it. (2) Generally speaking male roaches are more apt than females and young roaches are more apt than adults; but there are marked individual exceptions to this. (3) In the ability to learn and to retain what they have acquired roaches exhibit marked individuality. (4) Roaches that have acquired the habit of refusing to enter a specific dark place do not lose that habit when they moult. (5) During sickness and just prior to death the retentiveness of the roach is much impaired."

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RECENT LITERATURE ON THE BEHAVIOR OF VERTEBRATES

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Fish.—Parker (**28**) reports some experiments on the common chemical sense in Ammocœtes and Amiurus. The skin of the former can be stimulated by sour, bitter, salt, and alkaline substances, but not by sugar. The regions of the body are sensitive in the following descending order: mouth, tail, mid-trunk. Amiurus is unlike Ammocœtes in giving no response to quinine applied to the trunk and tail, and in showing no difference in sensitiveness between the trunk and tail. Cutting the various nerves which supply the body surface proved that the common chemical sense involved in these reactions depends on the free terminations of spinal nerves; while the sense of taste functions through the lateral accessory nerve and its taste-buds. Parker believes that not the common chemical sense but smell is in invertebrates the oldest of the three chemical senses, smell, taste, and the common sense, because its neurone is on the type of sensory neurones found among invertebrates and because invertebrates have a chemical distance receptor.

Shelford and Allee (**33**) find that of various atmospheric gases dissolved in water CO_2 has the most effect on fish, causing death in concentrations which merely reverse the reactions of lower invertebrates. A high N content does not affect fish seriously. These writers (**32**) have constructed a device whereby various parts of an aquarium can be supplied with water in which different gases are dissolved and the reactions of the fishes to the differing environments noted.

Goldsmith's (**17**) experiments on Gobius, Pleuronectes, Gasterosteus, and Syngnathus show that these fishes can by being fed from pincers be taught to investigate empty pincers, and by being shown a glass tube with a Mysis inside, to investigate empty glass tubes. The experiments in which she tries to prove color discrimination and association with colors are worthless because both smell and brightness errors are involved. They were condemned on the latter account by Piéron when the paper was read before the Institut.

Amphibians.—The sensibility of the frog to temperature has been studied by Babák (**2**), using a new method. The breathing

movements of a frog whose forebrain has been removed are of great regularity. When an area .5 cm. square on the skin was affected by radiant warmth (not touched), the breathing rate was quickened; cold brought near the skin slackened the breathing rate. The head was the most sensitive region. The frog's sensibility was apparently equal to or a little greater than that of a human being.

The educability of the axolotl has been demonstrated by Haecker (**18**). The animals learned to discriminate between meat and pieces of wood which they at first took for meat. The learning was poorest in the winter and spring, at the outset of the breeding season. Family likenesses in behavior were shown by the individuals in several stocks.

Riley (**30**) reports experiments made some years ago on young toads of the species *Bufo americanus*. He finds that they orient and move negatively to intense artificial light, positively to weaker (16 c.p.) artificial light and to diffuse daylight, positively to light filtered through a blue solution, and nearly as often negatively as positively to red light. No random movements were observed. They respond to contact in preference to light when both kinds of stimulation are presented; rough handling may produce a death-feigning response. They also sometimes react to contact by inflating the lungs with air.

Cummings (**12**) has made a number of careful observations on the ability of salamanders (*Molge cristata* and *Molge palmata*) to find their way back to water. He calls attention to the fact that the newts make compensatory head movements when carried about for short distances, which may help them in returning to the place from which they were taken. They are aided in finding water in which to breed by their marked tendency to walk downhill. They have also a homing faculty, which has not a very large range, and "probably consists in a topographical knowledge of the locality where the breeding pond is situated."

Birds.—Breed (**4**) and Bingham (**3**) both contribute experimental studies of vision in the chick. Breed's work is a continuation of that reported in his earlier monograph. He presents the following arguments in favor of color-discrimination by chicks: (*a*) The chicks showed no preference between a red and a blue at a certain brightness of each, but displayed preference as soon as the relative brightness was changed, hence it may be concluded that the red and the blue were, when no preference was shown, of equal brightness to the chicks: yet they learned to discriminate between them. (*b*) The acquired

discrimination was not affected by changing the relative brightness of red and blue. (*c*) "In the control test on white-blue, the rejection of blue continued perfectly when white was much brighter and when it was much less bright than blue." Both Breed and Bingham got positive results with size discrimination: one of Breed's chicks discriminated a circle 5 cm. in diameter from a circle 8 cm. in diameter; while Bingham, by gradually diminishing the difference in size between the two circles presented, found the limen of discrimination to be from 1/4 to 1/6 of a circle 6 cm. in diameter. One out of three of Breed's chicks apparently succeeded in distinguishing between a circle and a square. Bingham's chicks discriminated between a circle and a triangle when the apex of the triangle was on top, but since this discrimination broke down when the circle was presented with a triangle whose base was uppermost, the chick failing to choose the triangle, Bingham concludes that the chick was not reacting to form difference, but to "the unequal stimulation of different parts of the retina." The reviewer would conclude rather that the chicks were not possessed of an abstract idea of triangularity. A triangle with apex up is a different form from a triangle with apex down: the two have in common only the abstract quality of three-sidedness. The perception of form, as distinct from an abstract idea of form, is based precisely on the unequal stimulation of different parts of the retina. Bingham suggests, and to some extent uses, the method, in discrimination experiments, of presenting first a complex stimulus and gradually eliminating certain of the factors.

Phillips (**29**) notes that wild Mallard ducks can be tamed, while wild black ducks (*Anas tristis*) are untamable, and in a hybrid with three fourths *Anas tristis* traits the wildness was markedly dominant.

Craig (**9**) writes further of his experiments on inducing ovulation in the pigeon by preening the head and neck. He maintains that this stimulus does not produce ovulation by a simple reflex, but that the result is due to "the total situation including both the totality of present sense stimuli and also memory factors." It by no means always occurs: all the circumstances have to be favorable. One evidence that memory factors are involved is found in the fact that young doves which have never mated are more ready to enter into abnormal matings.

Observations on the drinking reflex in doves lead Craig (**10**) to the conclusion that the only innate stimulus for it is the touch of water on the inside of the mouth; that the ordinary pecking reaction first gets the dove's bill in contact with the water; that while pecking

is instinctively imitated, drinking is not; and that experience may associate the drinking reflex with all sorts of stimuli, and may even lead to the giving of drinking movements before going to the water.

Craig (11) finds that the behavior of pigeons in breaking out of the egg is like that of chicks, and consists in pushing out the large end of the egg, thrusting the bill through the shell, and turning around a few degrees between thrusts.

Ménégaux (27) calls attention to the lack of knowledge concerning the migrations of quails and suggests ringing them for study.

Mammals.—An elaborate study of the function of vibrissæ in the white rat has been published by Vincent (38). Her problems were two: the use of vibrissæ in maze running, and their use in discriminating rough from smooth surfaces. In connection with the first problem she constructed a novel kind of maze, with the pathways elevated and the sides removed. Rats with and without vibrissæ, with the vibrissæ on one side removed, with vibrissæ removed immediately after birth, anosmic rats with and without vibrissæ, blind rats with and without vibrissæ, and rats with the fifth nerve cut, were used with this maze. The results showed that the whiskers are very important as mediating a distance sense of touch. For investigation of the second problem the attempt was made to teach the rats to choose a runway lined with corrugated zinc rather than either of two with smooth sides. Rats without vibrissæ took much longer to make the discrimination. Next to the whiskers, the nose is useful as an organ of touch, for blind and anosmic rats learned to make the discrimination where rats with the infraorbital branch of the fifth nerve cut did not. Vincent notes the general sluggishness and lack of tonus in rats deprived of a sense: sensations act as a general stimulus to activity. A theoretical discussion of recognition and association concludes the monograph.

Vincent (37) has performed a service in tabulating the results of a number of investigators (Chievitz, Lindsay, Johnson, Slonaker, and Harris) on the structure of the eye in various mammals. The following headings are used in the table: fundus and tapetum lucidum, shape and color of optic disc, sensitive area, fovea, shape of pupil, divergence of optic axes, refraction, stereoscopic vision, rods and cones, decussation of optic nerve, pupil light reflex, refractive index of lens, refractive index of fluid media.

The Yerkes discrimination box was used in Lashley's (23) study of the white rat's discrimination of size and form. The animals showed a strong tendency, when they could be induced to attend to

the stimuli at all, to pay attention only to brightness difference. When the brightness error was eliminated, they learned to discriminate between a horizontal and a vertical line, and between rectangles whose width was varied; also between two circles of 30 and 50 mm. diameter respectively, the error increasing when the difference in size was reduced. They failed, however, to distinguish between a square and a circle when the area of the circle was made more than three fourths that of the square.

The first of the experimental series reported by Mr. and Mrs. Watson (39) on color responses in rodents consisted in testing a white rat and a gray Belgian hare with spectral red and green. It was found that the red had no stimulating value whatever, a result which corresponds to that of Washburn and Abbott's work with reflected light in the case of the rabbit. In the second series three rats and one rabbit were tested with spectral blue and yellow. The yellow proved to have a very low stimulating value, the blue a high value: this latter fact was also indicated, though not proved, by Washburn and Abbott's experiments. No evidence of discrimination based on wave-length rather than energy was found.

Cornetz (8) compares the rat's method of "remembering" the way to a vessel of water with that of an ant in remembering locality. The rat, according to Szymanski, remembers by reference to its own motor attitude: the ant can remember localities though entirely different motor attitudes are involved. (Compare the account of Hunter's research given below.) A curious misunderstanding is evinced by Cornetz's referring to the conception of learning through the dropping off of useless movements as "a finalistic theory."

Coburn (6) has observed "singing" in a common house mouse: it consisted of a rapid whole tone trill.

Sackett's (31) monograph on the porcupine begins with an account of the habits of the animal in the wild state. Sixteen individuals were experimented upon: all died soon. The first tests dealt with right- and left-handedness. The porcupine will reach for food with either fore-paw indifferently, but shows a disposition to use the "hand" on the side symmetrical with that of the hand that holds the food out to him, even though the food is always held in the same place. The animals were taught to use one hand in reaching for cabbage and the other hand in reaching for lettuce: the basis of discrimination was probably chiefly brightness.

The porcupine's manual dexterity can be considerably improved by training. He did well with puzzle boxes, including one with a

combination lock; in tests after a considerable interval he seemed to remember the order in which the parts of the apparatus should be attacked, but had lost dexterity in manipulating them. From this the author draws the interesting deduction that "associations on the mental side persist more perfectly than muscular co-ordinations." Sackett believes the unsocial nature of the porcupine rendered the presence of the experimenter on the scene of action innocuous as a source of error: this would be a dangerous statement if generalized. Form discrimination was tested in connection with the instinct to crawl into a den, by cutting holes of different form in a board. The forms used were a circle, a triangle, square, hexagon, ellipse, and rectangle. Such discrimination as resulted was based not on vision of the forms as a whole, but on examination of the edges: "the porcupine would run his line of regard, or visual axis, around the form until he came to the part which differentiated it from the others." Color and brightness discrimination were investigated by a rather unsatisfactory method: gray and colored papers were pasted on food boxes, which gives opportunity for identification by wrinkles, and the smell error was not eliminated quite rigidly. Animals which had learned to choose black rather than gray chose blue rather than green; and when dark blue was presented with light green and dark green with light blue, they chose the darker impression. If the choice of blue rather than green means that blue looked darker to them, their brightness values differ from those of the rabbit and rat, for which, as we have seen, blue has a high stimulating power. Porcupines learned to run the Hampton Court maze with great speed. The maze was situated out of doors on a slope; when it was rotated 90 degrees, the animals were naturally much confused, since the slopes were all changed.

Cole (7) finds touch, especially located in the nose and forepaws, very important in the raccoon. These animals do not seem to smell food more than a few inches away from it. Sight and hearing are both keen: the absolute limen for noise appears to be lower and the power of localizing sounds greater than in human beings. The following instincts of the young raccoon are noted: sucking, creeping, climbing, play, following (this wanes in the seventh month), fear, anger, curiosity.

The growth of English interest in experimental comparative psychology is illustrated by Smith's (35) careful study of color vision in dogs. A fox terrier, a Welsh terrier mongrel, and a whippet were the subjects. The apparatus offered a choice of four compartments,

with shutters carrying colored or gray cards under glass. The cards were 12 by 10 inches. Precautions were taken against identifying a card by surface or markings. Biscuit rewards were used. Smith, like others, found that the dogs would not work for punishment. A color was shown with each of a series of grays, and for every color some gray was found which was especially hard to distinguish from it. Green and yellow were confused with very light gray, blue with a medium gray, and red with a gray not quite so dark as the equivalent of blue. (This suggests brightness values like those for a human being: the low stimulating power of red and high stimulating power of blue which are found in rodents do not appear here.) With practice, however, there was no color that could not be distinguished from a gray. Another argument for the existence of true color vision is found in the fact that the dogs had more difficulty in discriminating grays than in distinguishing a color from the gray nearest to it. They could not discriminate if they were more than from one to two and a half feet from the cards. Many interesting points of the monograph must be passed over without comment because of the space limitations of this review. An important piece of interpretation is the following. The dogs displayed in their choices two types of behavior, which the author calls respectively "self-control" and "inhibition." The former type occurred when the dog in making for a particular shutter suddenly stopped, underwent apparently for some moments a conflict of impulses, and ended by rejecting the shutter. "Inhibition," on the other hand, happened where the dog's reaction to a shutter was suddenly checked, but no period of conflict or hesitation supervened. Smith thinks that the check in the "self-control" type of behavior comes from within the animal's mind, and implies "some species of ideal control"; while in inhibition the checking proceeds from the external stimulus. To the reviewer it does not appear self-evident that hesitation cannot proceed from a conflict of impulses whose stimuli are external, rather than ideal.

Johnson (**20**) gives in *Science* a review of a newspaper article by Pfungst, on the notorious case of the talking dog (Sechste Beilage zur Possischen Zeitung, 27 April, 1911). The dog, Pfungst reported, has evidently no consciousness of the meaning of his words, since he always gives his vocabulary in a fixed order. He does not imitate the pitch or intensity of his questioner's voice, nor, when he first uses a word, is it pronounced after a human being. The actual sounds which he produces are very few; all the rest being supplied by the hearer's mind. He has one vowel, between o and u; a ch and a nasal n, but

no b, d, k, l, or r. The disinterested observer cannot distinguish between *Hunger* and *Hahn* as the dog speaks them.

Shepherd (**34**) apparently succeeded in teaching two cats to distinguish between the sound of their names and other articulate sounds but his experiments are faulty in having been performed with the experimenter in plain view of the animals.

Von Maday's (**26**) book on the horse contains little that is of value to science. It has chapters on the senses and intelligence of the horse, and devotes a disproportionate amount of space to instincts, emotions and temperament, but there is almost no experimental evidence adduced in support of the statements on these various topics.

It appears that the problem of the behavior of "kluger Hans" is regarded, even by some respectable scientific authorities, as not having been satisfactorily solved by Pfungst's hypothesis of unconscious movements on the part of the trainer. Krall (**22**), a friend of von Osten's, has recently published an account of further experiments with the Berlin horse, and also of the performances of two horses of his own, which he has succeeded in educating to feats even more remarkable than those of Hans. Around this book a controversial literature has grown up of which our bibliography contains only the most important titles (**1**, **5**, **13**, **14**, **15**, **21**, **25**, **36**). Krall's horses not only find cube roots and answer questions with the aid of a conventional system of striking the hoof on the ground a certain number of times to represent certain letters; they have taken to making spontaneous remarks by the same means. The believers, like Krall and Te Kloot, not unnaturally become almost hysterical over the greatest discovery of the age, namely, that an animal may possess a mind of human capacity which has always lain dormant for want of proper means of education. Those who would, like Claparède, fain be conservative are almost persuaded; some, like Döring, are skeptical, while others are frankly abusive with regard to the fraud. Needless to say, the reviewer is unconvinced that the Elberfeld horses possess minds of the human type. Their performances are too wonderful. A few examples will suffice. Careful reading of the account of Krall's method of teaching the horses to multiply shows that the first time they were shown the printed multiplication sign they understood its meaning without being told. It would have been a remarkably clever child who could comprehend Krall's explanation of the process of extracting roots sufficiently well to use the method at once, as the horses did. Döring notes that the horses took no longer to solve difficult problems than to solve easy ones. On the other hand, it

seems probable that some influence besides the trainer's slight unconscious movements is involved. There are too many cases of correct performances when the horse could see no one. Moreover, the trainer is said in many instances to have been walking about and engaged in a variety of movements, which would make the signals very difficult to recognize. (The tests where the trainer was in ignorance of the correct answer to be given give ambiguous results.) The reviewer is inclined to think that the hypothesis of auditory cues deserves further attention.

The behavior of the monkey (*Macacus rhesus*) has been the subject of two recent studies, a short one by Franz (16) on right-handedness, and a series of careful observations by Watson and Lashley (24) on the development of a young monkey from birth. Franz found that "out of six monkeys one showed an apparent preference for the use of the right hand, and two preference for the use of the left hand," in reaching for food. The young monkey, according to Watson and Lashley, is practically complete in sensory development at birth. "There is some evidence that sounds were heard on the second day." The following reflexes were well established on the first day: sucking, grasping, muzzling, crying, sneezing, winking (though not in response to visual stimuli), "uncoördinated movements of the legs when the stimulus for grasping was removed, and an increased muscular tension in the legs in response to the mother's movements." Slight motor response to sound appeared on the second day; turning the eyes and head to follow a moving object on the third day, and on the fifth day reflex grasping at an object seen. The mother showed greatly increased timidity while nursing the baby: this is in contrast to the behavior of cats, which become abnormally brave under such circumstances. Self-imitation on the part of the young monkey was little if at all developed, nor was there any evidence "to show that the infant monkey ever gained a new activity by imitation." Many of his activities were acquired "only after many unsuccessful trials."

Finally, in Hunter's (19) monograph on "The Delayed Reaction in Animals and Children," we have a comparative study of the human and animal mind, of a type whose single previous representative has been the work of Hamilton. Hunter's subjects were twenty-two rats, two dogs, four raccoons, two boys and one girl six years old, a girl of eight and a girl of two and a half. The general nature of the problem was as follows. Light may be shown in one of three directions. If the subject goes to the light, it gets a reward. When this state of things has been grasped by the subject, a delay is introduced

between the showing of the light and the subject's release to go towards it. The problem is thus changed from that of going towards the light to that of going in the direction where the light appeared a short time before. The delays were gradually increased and diminished until a delay was established for each subject beyond which it could not "remember" in which direction the light had been shown. Only four rats were successful with delays of more than one second. One dog made a high record for thirty trials with a delay of three minutes. The raccoons succeeded with a delay of as long as twenty-five seconds. All the children except the two-year-old reached a delay of twenty minutes; the two-year-old failed at one minute. More significant than the maximal time of delay was the behavior of the subjects during the interval. All the rats "remembered" the direction of the light by orienting towards it and keeping the whole body oriented during the interval. The dogs were also dependent entirely on keeping a constant orientation, although it was an orientation of the head and not of the entire body. The raccoons showed their superiority to all the other animals by reacting correctly even though they moved about during the interval of delay. The children, of course, could recall the direction of the light without needing to keep their position constant. Hunter is not willing to grant, however, that the raccoons, like the children, used memory ideas. He prefers to conjecture that some organic sensations represented the direction of the light during the interval after its disappearance, thus assuming the function of a memory idea.

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SPECIAL REVIEWS

Tierpsychologisches Praktikum. KARL CAMILLO SCHNEIDER. Leipzig, 1912. Pp. 719.

Professor Schneider's volume on the psychology of animals is unique in that the discussion is presented in the form of a dialogue in which participate the psychologist, the monist, the vitalist, the physiologist, the Lamarckist, the biologist, the Darwinist, and occasionally the layman.

The dialogue form somewhat lightens the discussion, since occasionally one of the speakers expresses amusement, amazement, or disagreement. Because of the appearance of humor, the book is more readable than is the ordinary treatise of its bulk, yet there is the obvious disadvantage of the extreme multiplication of words.

The volume consists of three chief parts which deal with perception, action, and experience. Under these headings, some thirty odd separate discussions appear. The book is illustrated with one hundred and thirty-nine text figures, many of which are original, and the attempt is made both to bring into clear light the fundamental principles—presuppositions included—and the facts of the psychology of animals. Seventy-two experiments are used as the basis for the discussion of problems.

Professor Schneider has succeeded admirably in formulating problems and in stimulating critical consideration of the rapidly accumulating materials of behavior. He has failed, however, in the opinion of the reviewer, to do justice to the literature of his chosen topics. An analysis of the bibliography reveals that in a total of about two hundred and twenty-five titles, only twenty-five are those of American publications; and of the one hundred and thirty eight authors whose works are included, only eighteen are Americans. Similarly in the authors' index to the volume, we find that of the two hundred odd names listed, only twenty are American. In view of the fact that the psychology of animals is an American science, this neglect of American publications in a book which makes pretense at thoroughness of discussion is inexcusable. It is further noteworthy that Professor Schneider's knowledge of many of the American publications to which he refers is second hand. Indeed, even some

of the figures which he reproduces are taken from foreign reviews or translations of American books or monographs.

The *Tierpsychologisches Praktikum* is so extensive and so inclusive of topics important for the student of the psychology of animals that it is quite impossible to summarize, briefly, the results of the discussion. A mere listing of the topics of the thirty-one discussions will serve to acquaint the reader with the scope of the volume.

In Part 1, under perception, the topics include: (1) an introductory discussion of human behavior in which the typical human act, consisting of reception, association, and reaction, is described; (2) form perception, illustrated by studies of earthworms and spiders; (3) homogeneous and heterogeneous stimuli; (4) the visual field and the object; (5) the environment; (6) orientation in insects: (7) the identity theory, under which are considered identity, parallelism, and interactionism; (8) specific nerve energy; (9) central localization; (10) the peripheral subject. Under this topic one experiment deals with mind-blindness and, among other subjects discussed, are the old and new psychology, idealism, and realism.

Part 2, action, deals with the topics: (11) the tropism; (12) the method of trial and error—a discussion of problem solving in amœba and the infusoria; (13) purpose and accident; (14) the doctrine of compensatory excitation; (15) the mono-, bi- and tripolar hypotheses. This discussion is based chiefly upon the work of von Uexküll; (16) the psychic accompaniment; (17) the effect of feeling; (18) the intellectual value of instinct; (19) the different action types; (20) synthesis of the discussion.

Part 3 treats of experience under the following heads: (21) habit; (22) theories of memory; (23) animals' dreams; (24) the play of young animals; (25) the play of old animals; (26) the so-called intelligence of vertebrates; (27) experience; (28) the speech of animals; (29) objective psychology; (30) synthesis: the biological phantom (it is worthy of note that under this topic hysteria in the dog is the chief subject for consideration); (31) synthesis: the general plan.

As this array of topics indicates, the book deals in a general and conversational fashion with some of the most important aspects of the psychology of animals. It is semi-philosophical in its method and will serve better as a basis for critical discussion then as a students' guide.

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The Mechanistic Conception of Life. JACQUES LOEB. Chicago, 1912. Pp. 232.

The Mechanistic Conception of Life is a collection of semi-popular accounts of Loeb's experimental analyses of what goes on in the development of the egg, in the growth and movement of animals, and in the action of salts in connection with certain life-processes. It will serve as a convenient brief representation of the spirit and methods of a daring, ingenious and sagacious investigator.

Loeb uses these studies to point the moral that biological and psychological science should especially seek to reduce animal behavior to chemical reactions; and seems to consider that this mechanistic conception of life was a prime mover in his own discoveries. The actual lesson of the book seems to me rather that biological and psychological science should seek to enlist the devotion of men of genius. It is always interesting to have revealed the general world-view which a scientific worker either uses to make science advance or derives from the advances that he otherwise makes. But, to my mind, to use Loeb's studies as a stimulus to general argumentation for or against mechanism, vitalism, spiritualism, materialism and the like, is to make a rather trivial and inadequate use of them. It is as stimuli to matter-of-fact study of particulars, not to verbal argument about the meaning of sweeping statements, that they will do their proper work.

The two papers of closest relationship to psychologists' studies are "The Significance of Tropisms to Psychology" and "Pattern Adaptation of Fishes and the Mechanism of Vision." The reviewer has always been unable to appreciate the fundamental antagonism which Loeb seems to find between Jennings' work and his own. It appears to the reviewer that Jennings has illustrated Loeb's own soundest principles, for example, in carrying the analysis of the swarming responses of certain animals in response to certain conditions further than it had been carried, and that Loeb's proper retort should be to welcome the new facts and push the analysis still further by defining the mechanism, for example, for the avoiding reaction of Paramecium and the like. The paper on Pattern Adaptation seems to me a sample of genius at its worst, but it is probably more hopeful for science to have Sumner's observations suggest the idea that "vision is a kind of tele-photography" than to have them suggest that flounders have "minds" which look at scenery and then paint it on their backs by some teleological magic.

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Instinct and Experience. C. LLOYD MORGAN. New York: The Macmillan Co., 1912.

This book is an outgrowth of the discussion between Morgan and others which appeared in the *British Journal of Psychology* in 1910. The author defends the thesis that instinctive acts are functions of the lower brain centers. (He has in view only the higher vertebrates.) The physiological evidence for the thesis is drawn chiefly from Sherrington's work on decerebrate and spinal animals.

Consciousness, which is correlated with processes in the cortex, is a mere spectator of purely instinctive behavior. It receives information of this behavior and later comes to control and guide it. The behavior is then intelligent and perceptions then have meaning. It is assumed, then, "that experiencing is correlated with physiological processes in the cortex. . . . Instinctive behavior . . . affords those grouped data in consciousness, which may serve in some degree to explain (so far as it can be explained) the genesis of experience" (p. 21). A vague preperception may accompany the first instinctive act. Except for this all meaning is the result of individual acquisition. Thus instinct and intelligence differ both functionally and genetically.

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NOTES AND NEWS

THE present number of the BULLETIN, dealing especially with comparative psychology, has been prepared under the editorial care of Professor Margaret Floy Washburn.

THE following items are taken from the press:

THE Académie Française has awarded the Grand Prix Broquette Gonin, of the value of $2,000, to Professor Grasset, of Montpellier. The prize is for "the auther of a work, philosophic, political, or literary, which shall be judged to be of a nature to inspire the love of the true, the beautiful, and the good." Professor Grasset, who is known for his researches on the nervous system, is also the author of several works on questions of psychology, moral responsibility and the philosophy of practical life.